



Input to
Draft PITAC Report to Congress on the
Next Generation Internet (NGI)

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Congressional Charge to the PITAC

- The Next Generation Internet Research Act of October, 1998, requires the President's Information Technology (IT) Advisory Committee (PITAC) to review the implementation of the Next Generation Internet (NGI) initiative and report annually on:
 - **Advanced Networking Research:** Progress in NGI-funded advanced networking research
 - **NGI Testbeds:** Progress in implementing high-performance network testbeds,
 - **NGI Applications:** Progress in developing high-performance network applications
 - **Geographic Reach:** Addressing geographic penalties faced by rural institutions
 - **Minority- and Small- College Reach:** Addressing access by historically black and Hispanic-serving institutions and colleges and universities with fewer than 5,000 students
 - **Technology Transfer:** Flow of NGI ideas to industry
 - **Agency Coordination:** Effectiveness of coordination among the NGI agencies
 - **IT Leadership:** The extent to which Federal research support will maintain U.S. IT leadership



NGI Context

- The NGI is part of the HPCC/CIC/IT R&D programs
- PITAC recommended increasing HPCC/CIC funding by \$1.4 billion between FY 2000 and FY 2004
- In FY 2000 Congress appropriated \$235 million of the Administration's \$366 million requested increase
 - PITAC commends both the Administration and the Congress for this first installment of funding the PITAC's recommendations
- The Administration proposes a second installment of a \$ <TBA in February 2000> million increase in FY 2001, which includes proposed NGI funding



NGI Program

- The NGI was initially proposed to be a three year FY 1998-FY 2000 program funded at \$100 million per year with optional continuation for two more years
 - The Administration proposes continuation in FY 2001 and may include a fifth year of NGI funding in its FY 2002 budget proposal
- The FY 1998-FY 2000 NGI program has three goals:
 - Advanced networking research — the three major areas are:
 - Network growth engineering
 - End-to-end quality of service
 - Security
 - Two testbeds:
 - The 100x testbed would include 100 sites and have end-to-end performance 100 times faster than the Internet of 1997
 - The 1,000x testbed would include 10 sites and have end-to-end performance 1,000 times faster than the Internet of 1997
 - 100 “revolutionary” applications that require NGI technologies



NGI Budget Profiles (Dollars in Millions)

Agency	FY 1998		FY 1999		FY 2000	
	Requested	Actual	Requested	Actual	Requested	Estimate
DARPA	\$40	\$42	\$40	\$45	\$40	\$36
NSF	10	23	25	25	25	25
DOE	35	0	25	15	15	0
NASA	10	10	10	10	10	15
NIH/NLM	0	5	5	5	8	5
NIST	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>	<u>5</u>
TOTAL	\$100	\$85	\$110	\$105	\$103	\$86



PITAC's Assessment of the NGI (1)

- The NGI program has already achieved many of its FY 1998-FY 2000 goals and is on schedule to achieve the remainder of those goals early in FY 2001
- NGI funding shortfalls have delayed or eliminated some activities
 - FY 1998 NSF funding delayed till early FY 1999
 - Testbed deployment and applications development effectively delayed one full year
 - DOE received no NGI funds in either FY 1998 or FY 2000
 - There has been less NGI R&D in network engineering, measurement, performance, and middleware
 - There has been less R&D in NGI applications technologies:
 - Collaboratories
 - Remote operation of advanced scientific instruments



NGI's Advanced Networking Research (1)

- NGI agencies have a strong, balanced collection of networking research projects that address all key topics:
 - Network growth engineering
 - Network modeling
 - Monitoring, control, analysis, and display
 - Adaptive network management
 - Bandwidth and traffic management
 - Middleware for visualization applications
 - Monitoring and analysis of IP packet flow and performance
 - Resource management
 - Scheduling
 - Test and measurement tools
 - Web performance
 - Integration
 - Application to network interfaces
 - Protocols and standards
 - Data delivery
 - Group communications
 - Hybrid land-based, wireless, and satellite networks
 - Multicast
 - Multimedia networking



NGI's Advanced Networking Research (2)

- Network growth engineering (continued)
 - Managing lead user infrastructure
 - Networks for data intensive applications
 - Optimizing distributed application performance
 - Smart environments
- End-to-end quality of service
 - High performance routing and switching
 - Managing denial of service
 - Managing quality of service in hybrid land-based, wireless, and satellite networks
 - Multi-protocol label switching
 - Performance trade-offs
 - Reservation of service
 - Testbeds (in cooperation with Internet2 and industry)
- Network security
 - Standards such as PKI
 - Testbeds
- New technologies
 - Hybrid land-based, wireless, and satellite networks
 - Optical networking technologies
 - Ultra high bandwidth on demand



NGI Testbeds

- The NGI program has established two testbeds :
 - The 100x NGI testbed connects more than 150 sites (goal was 100)
 - The 1,000x Supernet testbed connects 15 sites (goal was 10)
- The 100x testbed includes:
 - Federal NGI networks
 - NSF's vBNS
 - DOE's ESnet
 - NASA's NREN
 - DoD's DREN
 - The academic sector's Abilene (Qwest, Nortel, Cisco, and the University of Indiana) network



Additional NGI Testbeds (1)

- NASA
 - NGIX-West — OC-3/OC-12 ATM and planned OC-48 packet over SONET connectivity point with performance measurement capabilities
 - Multicast Internet eXchange (MIX) — Test and deploy protocols that scale
 - NREN Multicast — Native multicast data distribution over wide area networks
 - NREN OC-48 — 2+ Gbps aggregate flow among three endpoints
 - CEOS/GOIN Earth Science International Demonstrations



Additional NGI Testbeds (2)

- DOE
 - EMERGE — ESnet/MREN Regional Grid Experimental testbed
 - Authentication, collaborations, e-commerce, Globus, health sciences, multicast, QoS, remote instruments, scheduling, security, standardized tool sets, visualization, weather
 - 100 Mbps end-to-end connectivity to five universities, four DOE laboratories, and STAR TAP
- Multi-agency Qbone
 - DOE — QUALIT architecture for IP differentiated services
 - NASA
 - QoS mechanisms, interoperability, testing, and applications prototyping
 - NGIX-West connects multiple university networks nationwide
 - NSF's vBNS backbone



NGI Networking Applications (1)

- The NGI agencies have developed and documented more than 90 NGI applications
- More NGI applications are being developed without explicit NGI funding
 - At universities — through their access to NGI testbeds
 - Jointly by universities and industry



NGI Networking Applications (2)

The 90+ documented NGI applications organized according to the categories in the NGI Implementation Plan (many applications belong to more than one category):

Applications Technologies

Collaboration Technologies	32
Digital Libraries	6
Distributed Computing	6
Remote Operations	17
Security and Privacy	4

Disciplinary Applications

Basic Science	37
Crisis Management	1
Education	13
Environment	15
Federal Information Services	4
Health Care	28
Manufacturing	9



Reach

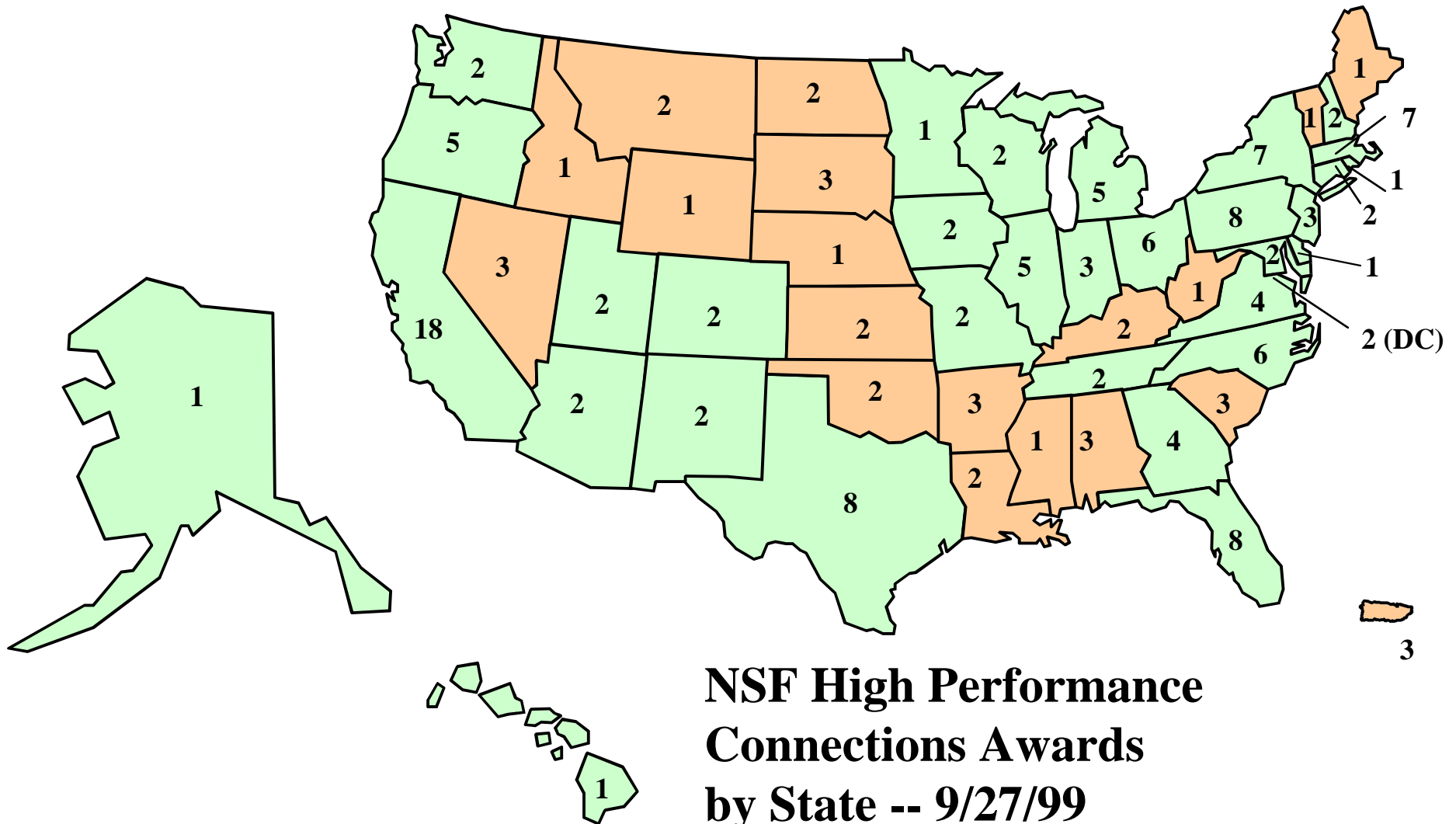
- NGI is an R&D program to develop the technologies and applications required as foundations for the next generations of the Internet.
 - It is a relatively small initiative that funds peer-reviewed research proposals.
 - It cannot fund institutions where research is not emphasized and where there is little experience developing advanced networking or applications.
- Consequently, the NGI initiative cannot directly address reach to rural, inner-city, minority, or small institutions.
- However, the NGI program has broad geographical reach, and NSF has a special program to address minority college reach (next three slides)



Geographic Reach (1)

- There are more than 200 NGI sites
 - Every state in the U.S. has at least one NGI site (as shown in the map on the next slide)
 - These include 40 sites in the 19 states in the Experimental Program to Stimulate Competitive Research (EPSCoR)
 - Connectivity to Alaska and Hawaii has been substantially improved

Geographic Reach (2)





Minority and Small College Reach (1)

- The NGI was not funded to address Internet access for historically black, Hispanic-serving, Native American, or small colleges and universities.
- However, as part of its standard peer review process, NSF has awarded High Performance Connection grants to two historically black and five Hispanic-serving institutions. This is one more than reported last year.



Minority and Small College Reach (2)

- In September 1999 NSF made a four-year \$6 million award to EDUCAUSE to help minority-serving institutions develop campus infrastructure and national connections.
 - Award addresses Hispanic, Native American, and Historically Black Colleges and Universities
 - Scope includes:
 - Executive awareness, vision, and planning
 - Remote technical support centers
 - Local network planning
 - Local consulting and training
 - Satellite/wireless pilot projects
 - New network technologies: Prototype installations
 - Grid applications



Technology Transfer (1)

- NGI technology transfer to U.S. industry is substantial — the structure of the NGI program enables automatic immediate direct flow of NGI ideas to industry
 - U.S. industry participates in NGI programs and projects
 - The NGI testbeds are managed through cooperative agreements between NGI agencies and telecommunications companies
 - MCI WorldCom deploys NSF's vBNS
 - Sprint deploys research components of NASA's NREN and DOE's ESnet
 - AT&T deploys DoD's DREN
 - The university/industry Abilene network in which Cisco, Nortel, Qwest, and the University of Indiana participate, is part of the NGI testbeds
 - These companies are free to commercialize NGI technologies that they develop
 - In January 2000, a contract was awarded to Qwest with a potential value of \$50 million to provide DOE's ESnet communications services



Technology Transfer (2)

- U.S. industry participates in NGI applications testbeds for the development of standards
 - For example, the joint NGI/Internet2/industry national and international scale Qbone differentiated services testbed
- U.S. industry participates in NGI meetings and workshops
 - Bridging the Gap Workshop (August, 1999)
 - DARPA/NSF/NIST Networking Research Principal Investigator (PI) Meeting (December, 1999)
 - DOE PI Meeting (October 1999)
 - Public Key Infrastructure for Advanced Networking Technologies Workshop (April 2000)
 - End-to-End Gigabit Networking Workshop (August 2000)



Technology Transfer (3)

- Continued NGI technology transfer is enabled by having 150 universities, where new generations of industry workers are educated, also participate directly in NGI programs, projects, and workshops
 - More than 100 universities are connected to the NGI testbeds
 - Researchers, students, and employees at these universities collaborate with industry and Government personnel in:
 - Deploying, operating, measuring, and improving the performance of the NGI testbeds
 - Developing advanced applications that are run over the NGI testbeds

Technology Transfer (4)

- Start-up companies are formed as NGI PIs and researchers join new companies as chief technologists
- This technology transfer has negative consequences:
 - Fewer university researchers
 - Fewer educators of future generations of networking and applications researchers
 - Fewer Government program managers



Interagency Coordination (1)

- Large Scale Networking Coordinating Group (LSN CG)
 - Coordinates multi-agency NGI R&D
 - Participants include NSF, DARPA, NIH, DOE's Office of Science, NASA, NIST, AHCPQ, NIST, NOAA, EPA
- LSN Teams
 - Joint Engineering Team (JET)
 - High Performance Networking Applications Team (HPNAT)
 - Network Research Team (NRT)
 - Internet Security Team (IST)
 - Participants:
 - LSN agencies
 - Cisco, Gigapop operators, MCI WorldCom, Qwest, UCAID/Abilene, and university networking departments
- National Coordination Office for Computing, Information, and Communications (NCO/CIC)
 - Coordinates LSN and NGI program planning, budgeting, and assessment
 - Supports LSN CG and the LSN Teams
 - Provides single point of contact for information about the NGI program



Interagency Coordination (2)

- Coordinated projects
 - Effective coordination is accomplished through informal mechanism
 - Joint agency funding of projects has proved to have high administrative barriers
 - Agencies jointly developed the NGI Implementation Plan
 - Agencies serve on other agencies' peer review panels and participate in joint PI reviews, thereby assuring that program implementations remain coordinated — examples are:
 - DOE PI Meeting (October 1999)
 - DARPA/NSF/NIST Networking Research Principal Investigator (PI) Meeting (December 1999)
 - Agencies coordinate assessment and planning at joint workshops
 - Bridging the Gap Workshop (August, 1999)
 - Public Key Infrastructure for Advanced Networking Technologies Workshop (April 2000)
 - End-to-End Gigabit Networking Workshop (August 2000)
 - Individual agency NGI testbed networks interoperate and peer at NGI-West, NGI-Midwest, and will do so at the future NGI-East



NGI Leadership

- Federal IT R&D program and LSN CG provide overall direction to coordinated R&D in programs designed through strong on-going interactions with academia and industry
- NGI program maintains U.S. leadership in advanced networking capabilities by funding R&D in leading-edge technologies and applications
- PITAC NGI reviews provide assessment and recommendations to maintain U.S. IT (including NGI) leadership



Most Significant Agency Accomplishments

- DARPA
 - Optical networking
 - Applications on the 1,000x Supernet testbed
- NSF
 - 100x testbed
 - Broad spectrum of applications under development
- DOE — Collaboratory technologies and tools
 - Examples are China Clipper tools and Combustion Corridors
- NASA — NGIX-West
- NIST — Collaboration with manufacturers for standards
- NIH/NLM
 - Health care applications
 - Community awareness of NGI's potential usefulness



PITAC Assessment of the NGI (1)

- In addition to meeting its own goals, the NGI program has responded positively to all FY 1999 PITAC recommendations:
 - Measure network performance at NGI sites
 - NLANR is implementing standardized measurement platforms for throughput, latency, and jitter at 97 NGI sites
 - Measuring throughput on the NGI backbone
 - Developing automated standard formats for reporting performance data
 - Increase emphasis on end-to-end applications
 - Now that the NGI testbeds are deployed, the NGI program is focusing on improving the end-to-end performance of advanced applications requiring NGI technologies
 - Bridging the Gap workshop focused networking research on applications needs
 - Demonstrate Gbps (Gigabits or 1,000 bits per second) applications
 - SC99 HDTV demonstration of 2.4 Gbps throughput, 54.7 TB (Terabytes or trillions of 8-bit bytes) of data transferred



PITAC Assessment of the NGI (2)

- The NGI program is also responding to the recommendations for R&D in Scalable Information Infrastructure that were made in the PITAC February 1999 report “Information Technology Research: Investing in Our Future”
 - Collect and analyze performance data
 - NGI performance measurement program
 - Model and simulate network behavior
 - DARPA and NSF research programs
 - Conduct R&D in optical, wireless, and wired technologies
 - DARPA Supernet program
 - Conduct R&D on scaling the Internet
 - DARPA and NSF research programs



PITAC's NGI Recommendations (1)

- Fund the six NGI agencies at their full Presidential requests in FY 2001 and FY 2002
 - The research community needs stable multi-year funding in order to fully realize their potential contributions to advanced networking
- Complete the NGI program according to the plans set forth in the FY 1998 NGI Implementation Plan as updated in:
 - NGI planning documents
 - Agency NGI solicitations
 - HPCC/CIC/IT R&D Supplements to the President's Budget (Blue Books)
 - HPCC/CIC/IT R&D Implementation Plans



PITAC's NGI Recommendations (2)

- NGI R&D should continue its essential role in the IT R&D initiative through its research in networking technologies and applications that require NGI performance and services
 - For example, the NGI should continue to support the GRID, whose goal is to meet distributed high performance computing requirements
- Continue annual PITAC reports to Congress on NGI R&D
 - May be part of a larger IT R&D reporting process



PITAC's NGI Recommendations (3)

- As stated in its April 1999 NGI review, PITAC recommends that Congress consider funding a new program in which NGI research institutions act as aggregators and mentors for nearby smaller or disadvantaged institutions. Since this would be primarily infrastructure, not networking research, it should not be part of the NGI or IT R&D programs.